

October 26, 2000

Future Directions for Far-Infrared Sources

Workshop Summary

Michael C. Martin, Wayne R. McKinney

On October 18, 2000 we convened a workshop to investigate the science that could drive a new synchrotron-based far-infrared program at the ALS. Topics emphasized the far-IR research that could be enhanced by a new high-brightness far-IR facility. Since the evolution of such a program involves source development, workshop topics also included measurements of and proposals for producing coherent high-brightness far-IR from a storage ring.

Nearly forty people attended the workshop. Please refer to the attendee's list and the program schedule appended to the end of this document.

- **Morning Session:**

Mike began the program by briefly giving the reason for the workshop, describing activities at the ALS since the previous year's workshop, and presenting the recently funded LDRD research we plan to perform investigating coherent radiation at the ALS.

Dimitri Basov from UC San Diego then took over as chair and introduced Prof. George Gruner from UC Los Angeles. George spoke about his group's recent measurements of the far-IR conductivity of electrons on strands of DNA. He showed that the DNA's conductivity changes significantly with the hydration state of the DNA molecule. He stated that if enough intensity was available from a new far-IR facility, high spatial resolution far-IR measurements (~1 micron resolution) would be possible which could measure the different folding states of DNA molecules in a sudden

mixing setup. George brings a very interesting biological research application and is enthusiastic in his support for a new far-IR ring at the ALS.

The second invited speaker was Prof. Al Sievers of Cornell. Al has a deep knowledge of infrared measurements including recent investigations of coherent far-IR radiation from the Cornell LINAC. His talk discussed how high intensity excitations of atoms could create intrinsic localized vibrational modes in periodic lattices. He presented modeling his group has done, and a demonstration experiment they were able to perform using a high-field RF cavity to induce localized modes in a magnetic system. To study these interesting localized modes in crystals, one would need a very high intensity far-IR source that could drive the sample into a non-linear response regime. Non-linear phenomena such as these localized modes would be an important scientific arena for a new coherent far-IR facility.

After a coffee break, Wayne McKinney chaired the late morning session and introduced Prof. Richard Saykally of UC Berkeley's Chemistry Department. Rich presented results from his laboratory where they are measuring the Vibrational Rotational Tunneling (VTR) of small water clusters at extremely high resolution. They have built a number of tunable far-IR laser sources to measure the VTR spectral features of several water bands. However this research is very labor-intensive and cannot cover the entire spectral range of interest (20 to 600 cm^{-1}). His

research thrust is to fully understand the hydrogen bonding interactions between individual water molecules in small clusters so that ultimately a much better understanding of the properties of water will result. Rich is excited about the possibility of using a high-brightness far-IR source with an ultra-high resolution step-scan FTIR spectrometer to better perform these important measurements.

Prof. Paul Richards of UC Berkeley then gave a brief impromptu talk about developments in far-IR detector technology. He has been working in this field continuously for forty years and he showed throughout this time the speed at which far-IR measurements can be done has doubled every 12 months continuously for 40 years! He also pointed out that a number of space-borne far-IR telescopes are planned by NASA at a cost of \$10 to \$100 million each, and every one of them will need high-precision testing which could be an excellent role for a new far-IR facility at the ALS.

John Byrd of the ALS Accelerator Physics group then finished up the morning session with some of the initial design ideas his group has for a coherent far-IR ring. The present ideas include a six-fold symmetric ring which would have 12 bend-magnet ports specifically designed for extracting long-wavelength radiation. It would use the existing ALS LINAC and booster ring as an injection system and could operate in two modes. One would be a 'normal' high current incoherent synchrotron mode that would allow the infrared endstations to begin doing excellent science. The second mode would have very short electron bunches so that it would produce coherent far-IR radiation for both more intensity and also femtosecond timing measurements. Mode 1 could be built first with Mode 2 capabilities added second. These IR ring ideas generated much positive discussion from the group.

• Afternoon Session:

Following lunch, Mike and members of the

ALS accelerator physics group gave a brief tour of the area on top of the ALS booster ring where a new coherent IR beamline might be constructed. We discussed how the shielding roof and walls were poured in place and are therefore much more stable against vibrations. The attendees were also able to see how much room would be available for individual beamline endstations.

We all returned to the workshop room and Mike took over as chair for the next three talks. Larry Carr of the NSLS presented a talk on the current status of the U12IR beamline and some of the Far-IR science they have been doing. He reported on the very low frequency performance of a new FTIR spectrometer recently installed on U12IR, and of interference fringing that was observed. After some work, they found that the source of the fringing is a reflection off of the vacuum chamber from earlier in the bend. Larry then presented a sampling of the science: testing mm wave windows for a new telescope array, studies of LaMnO_3 , and finally pump-probe measurements of photoexcitation and relaxation in superconductors. Larry also presented some measurements they have done of coherent far-IR bursts resulting from microbunching of the electrons in their ring. These measurements showed the characteristic n^2 intensity profiles of coherent radiation, but this radiation comes in quasi-random bursts making it not very useful as a far-IR source.

The next speaker was Prof. Daniel Mittleman of Rice University. He presented some of his research that uses single cycle terahertz pulses to perform spectroscopy and imaging in the far-IR (typically 3 to 100 cm^{-1}). The THz pulses are created by a femtosecond laser pulse incident on a special antenna that then radiates a single cycle pulse. This technique has the advantage of directly measuring the electric field amplitude, however it does not provide a high-power source; typical power values are 10-100 nW per pulse. Dan showed some fascinating data where a large absorption is observed from nanometer sized water pools trapped inside of micelles and that the

absorption frequency shifts dramatically depending on the size of the cell. He also showed several examples of how one can obtain high resolution depth profiles of what is inside an object by measuring the time delay of the reflected THz pulses.

Chris Homes of BNL's Physics Department then presented some of his work on strongly correlated electron systems in the very long wavelength region using the U10A far-IR beamline at the NSLS. This beamline is similar to the ALS 1.4.2 beamline with the same instrumentation. Chris showed various measures of the beamline performance and how it is better than a thermal IR source. He then spent the bulk of his talk discussing recent results on the $(\text{Sr,Ca})_{14}\text{Cu}_{24}\text{O}_{41}$ two-leg spin ladder system. A possible c-axis collective mode was suggested by his far-IR data, but he needed to measure further in the IR to determine it better. By switching to a different instrument that can use a Si beamsplitter, he was able to push his low-frequency data down to 8 cm^{-1} and could resolve this new mode. Chris is enthusiastic about a new far-IR ring, which could help make these very far-IR measurements much easier and would therefore help the infrared community as a whole.

After a break, the workshop continued with its final session chaired by Zack Schlesinger of UC Santa Cruz. Paul Dumas from the LURE synchrotron near Paris discussed far-IR studies of gases adsorbed onto solid surfaces. This research is performed at grazing incidence and therefore requires a high-brightness source. The subtle nature of the far-IR modes also requires a very stable, low-noise source. He showed several examples of new science that could be done if a new far-IR source was built.

Christian Bernhardt from the Max Plank Institute in Stuttgart gave the final presentation of the day. He discussed his research with a far-IR ellipsometry apparatus he built at the U4IR beamline at the NSLS. These measurements are very powerful and reliable, however they need high brightness sources as

they are performed at fairly large angles from the sample normal, with a high degree of polarization and no focussing for the incident beam. He showed a number of interesting results from high-temperature superconductors and other strongly correlated electron systems. He is also very interested in a higher flux far-IR source to enable yet more ellipsometry measurements on smaller samples.

• Discussion:

At the end of the presentations, Mike thanked everyone for participating and opened the workshop to a round-table type discussion. The entire group stayed until after 5pm going over several issues of the day. We were very pleased that the overall tone of all those in attendance was quite enthusiastic for the construction of a new far-IR facility at the ALS. The potential science that could be enhanced by such a facility was deemed very worthwhile and the value of having a West Coast Far-IR synchrotron facility was highlighted. Building a stable coherent far-IR ring would result in a large enhancement over current far-IR capabilities worldwide.

• Conclusions:

The overall conclusions and recommendations of the workshop are:

- A dedicated Far-IR facility should be built at the ALS.
- The most enthusiastic supporters of this new facility are Dimitri Basov, Zack Schlesinger, George Gruner, Richard Saykally, Joe Orenstein, and Chris Homes. They all are eager to help in proposal writing for such a facility and to help guide in the selection of scientific apparatus for end-stations.
- The ALS accelerator physics group should continue firming up design plans and begin cost estimates. Once the technical details are pinned down, a full proposal should be written to fund and build the new Far-IR facility.

List of Attendees:

Joe Orenstein	University of CA, Berkeley
George Gruner	University of CA, Los Angeles
Zack Schlesinger	University of CA, Santa Cruz
Paul Richards	University of CA, Berkeley
Richard Saykally	University of CA, Berkeley
Dimitri Basov	University of CA, San Diego
Roland Hirsch	DOE
Al Seivers	Cornell University
Daniel Mittleman	Rice University
Larry Carr	NSLS, Brookhaven National Lab
Paul Dumas	LURE
Christian Bernhardt	Max Plank Institute, Stuttgart
Todd Smith	Stanford University Hansen Laboratory
Gerald J. LaPeyre	Montana State University Bozeman
Tim May	Canadian Light Source
Chris Weber	University of CA, Berkeley
Ted Raab	University of Colorado at Boulder
Ronald Cornwell	Canada
Lora Nugent-Glasdorf	JILA
Neville Smith	LBNL
John Byrd	LBNL
Dave Robin	LBNL
Hoi-Ying Holman	LBNL
Robert Kandl	LBNL
Ying Wu	LBNL
Christoph Steir	LBNL
Allen Johnson	University of Nevada, Las Vegas
Wim Leimans	LBNL
T.J. Wilkinson	LBNL
Warren Byrne	LBNL
Bruce Samuelson	LBNL
Susan Spiller	
+ 5 more students	
<i>Organizers:</i> Michael C. Martin Dimitri Basov Zack Schlesinger Gwyn Williams Wayne R. McKinney	LBNL ALS UC San Diego UC Santa Cruz Jefferson Lab LBNL ALS

Far-Infrared Workshop Program

2000 ALS Users' Meeting
Wednesday October 18, 2000

Room 4-102B

8:30 *Continental Breakfast*

9:00 Michael Martin Welcome
ALS

Chair: D. Basov, UCSD

9:20 George Grüner "Motion of electrons on the DNA double helix"
UCLA

9:55 Al Sievers "Generating Intrinsic Localized Vibrational and Spin Wave Modes in
Cornell Nonlinear Periodic Lattices"

10:30 *Coffee Break*

Chair: W. McKinney, ALS

10:50 Richard Saykally "Far-IR VRT Spectroscopy of Clusters"
UC Berkeley

11:25 Paul Richards "Far-IR detector developments"
UC Berkeley

11:35 John Byrd "Ideas for a dedicated IR source at the ALS"
ALS

12:10 *Lunch (ALS Patio)*

12:50 Brief tour of proposed location for a new far-IR ring

Chair: M. Martin, ALS

1:20 Larry Carr "Far Infrared Science at the NSLS"
NSLS, BNL

1:55 Daniel Mittleman "Spectroscopy and Imaging with Single-Cycle Terahertz Pulses"
Rice

2:30 Chris Homes "Infrared studies of correlated systems at very long wavelengths at the
BNL NSLS"

3:05 *Coffee Break*

Chair: Z. Schlesinger, UCSC

3:25 Paul Dumas "Far-IR studies of solid-gas interfaces"
LURE

4:00 Christian Bernhard "Far-Infrared Ellipsometry using a Synchrotron Light Source"
MPI Stuttgart

4:35 *Roundtable discussion*